TUTORIALS

Magnet Systems for Unilateral Magnetic Resonance

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Magnetic Resonance in its various implementations has proven to be among the most powerful, and certainly most general, analytical techniques available to modern science. Following several decades of development, the state of the art for clinical MRI and liquid/solid state spectroscopy instruments is very highly evolved, generally featuring expensive high field superconducting magnets.

While low field permanent magnet based MR instruments feature inherently low SNR, with thermal polarization, the ideas of unilateral magnetic resonance (also termed ex situ NMR or single sided NMR) have captured the imagination of many researchers world-wide. These instruments are attractive and exhilarating because the development work is very hands-on and still very early stage - which means that new, simple, physical ideas are readily translated to new designs.

Low field portable magnets (which includes luggable magnets), instruments, and associated measurement developments, over the last decade, will be reviewed in this tutorial lecture.

Our emphasis will remain true single-sided instruments rather than the more general topic of low field magnetic resonance. Instrument developments over the last decade already demonstrate a number of trends, which permit reasonable extrapolation to future instruments and measurements. The tutorial will therefore conclude with judicious speculation on future unilateral MR instruments and measurements.

Diffusion in porous media

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A geometrical confinement considerably affects the diffusive motion of the nuclei and the consequent signal attenuation under inhomogeneous magnetic fields. In the tutorial lecture, we focus on theoretical and numerical aspects of restricted diffusion in NMR. Starting from the classical Bloch-Torrey equation, we obtain the free induction decay (FID) and the spin-echo or gradient-echo signal in a compact matrix form. Each attenuation mechanism (restricted diffusion, gradient dephasing, surface or bulk relaxation) is represented by a matrix which is constructed from the Laplace operator eigenbasis and thus depending only on the geometry of the confinement. In turn, the physical parameters (free diffusion coefficient, gradient intensity, surface or bulk relaxivity) characterize the "strengths" of the underlying attenuation mechanisms and naturally appear as coefficients in front of these matrices. Once the Laplacian eigenfunctions for a given confinement are found (analytically or numerically), further computation of the macroscopic signal is more accurate and much faster than by using conventional simulation methods. The matrix technique is actually a simple numerical tool to deal with arbitrary gradient waveforms, including simple or stimulated, single or multiple spin echoes. We illustrate its efficiency by considering restricted diffusion in simple domains: a slab, a cylinder, and a sphere. Classical and recent theoretical advances achieved by using Laplacian eigenfunctions are overviewed.